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Bulletin No. 3

UNION OF SOUTH AFRICA

DEPARTMENT OF MINES

GYPSUM
IN THE
UNION OF SOUTH AFRICA

BY

B. WASSERSTEIN, Ph.D.
Assistant Geologist

PUBLICATION OF THE GEOLOGICAL SURVEY DIVISION

The Government Printer, Pretoria
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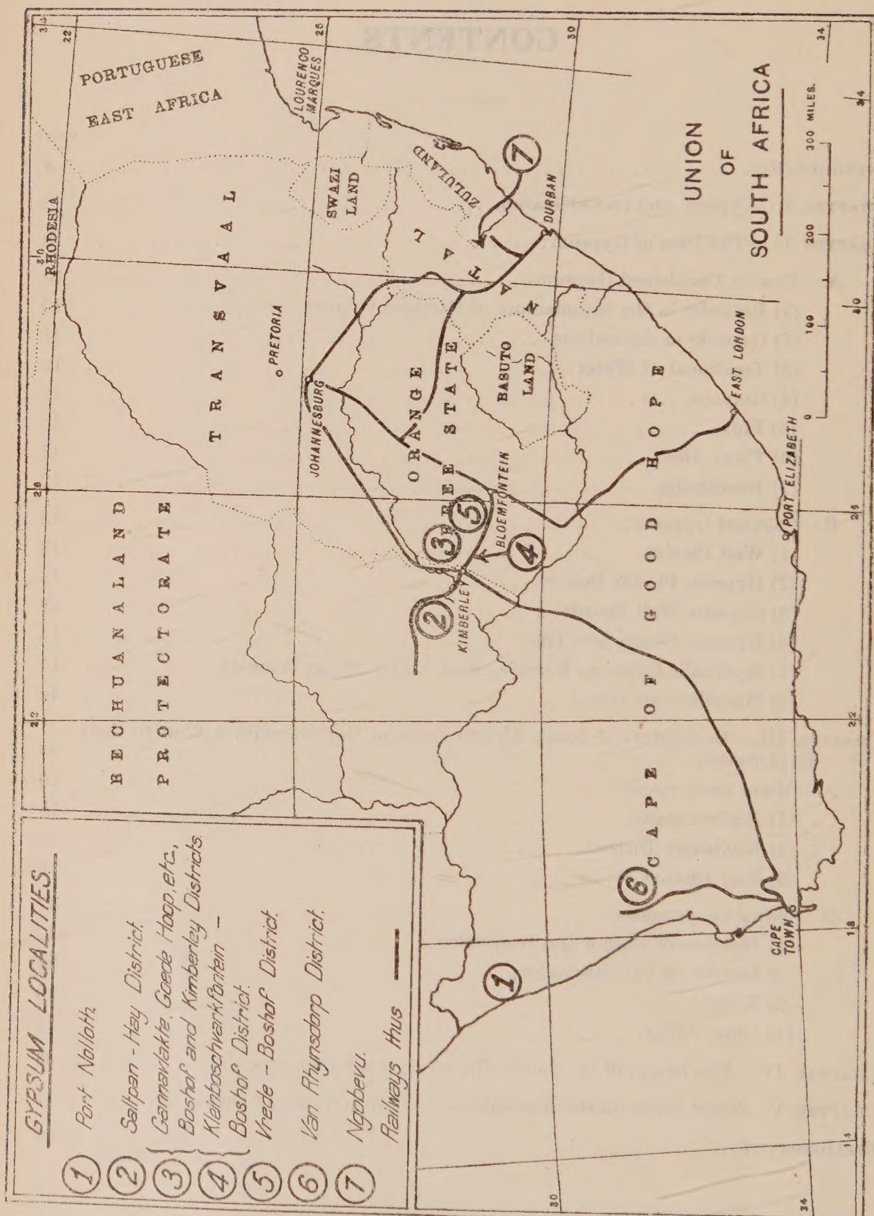


Key Map showing Gypsum Localities and Relevant Railways.

GYPSUM IN THE UNION OF SOUTH AFRICA

By B. WASSERSTEIN, Ph.D.
(Assistant Geologist).

INTRODUCTION.

Actuated by the present building boom, the public has again become interested in the possibility of manufacturing building materials from South African gypsum. Published information concerning these deposits has been scanty. In 1919 Professor M. Rindl published a short article (*S.A. Journal of Industries*, p. 1043). About that time Wybergh collected a certain amount of useful data (Memoir 11, Geological Survey); more recently Marquard roughly summarised the position of gypsum in this country (*Jl. of Chem. Met. & Min. Soc. of S.A.*, Aug., 1931, p. 29). Somewhat fuller information was wanted, and the writer was instructed to visit the more important gypsum occurrences. This bulletin is intended to supply the available information. It is hoped that hereby a serious obstacle to progress in developing an industry will be removed and that this potential wealth will be exploited.

Gypsum occupies an important niche among the "base minerals" (a convenient collective term for most minerals used in industry), as is evident from the table giving some statistics for America, where gypsum products are utilised extensively:—

Year.	Mine Production.	Sales.		Total Value.
		Crude.	Calcined.	Dollars.
	(Short tons.)	(Short tons.)	(Short tons.)	
1933..........	1,249,036	455,247	912,963*	—
1932..........	1,364,972	505,461*	1,031,284*	—
1931..........	2,559,017	773,185	1,593,753	20,801,357
1930..........	3,741,393	989,591	2,191,376	27,051,484
1929..........	5,016,132	1,065,697	3,361,580	31,292,969
1928..........	5,102,250	999,412	3,641,385	32,036,163
1925..........	5,678,302	1,014,135	4,096,357	47,577,240

* Includes Imports.

World production of gypsum in 1930 was nearly $12\frac{1}{2}$ million short tons—that of the British Empire accounting for $2\frac{1}{4}$ million. The South African production of crude gypsum in 1933 was valued at over £10,000—nearly all of which was used for cement making.

Viewing our gypsum deposits from the economic angle, there are two points to be considered: grade and reserves. The bulk of our gypsum does not attain the high purity found in the deposits of the

large world producers like Canada, the United States of America, France, Yugo-Slavia, etc. Proximity of source offsets this imperfection, and with an attempt at improvement of the present crude cleaning methods this country could produce burnt and unburnt gypsum for nearly all derived products in which a dead-white colour was not essential. Much of our calcined gypsum will show a faint coloration, but this will hardly detract from its suitability in the building trade.

Coming to the second consideration it may be pointed out that our reserves are not comparable with those of, e.g. the United States, but, as is shown in a later chapter, they are large enough to satisfy the demand determined by markets within our frontiers for a great many years to come. Very little prospecting for gypsum has been done so far and the accurate estimation of our reserves is not practicable. The costs of quarrying and cleaning are low; the known reserves, considering our possible needs, are enormous; the geographical positions are certainly not unfavourable—these factors combine to provide the industry with the raw material on economic lines.

The all-important question of costs may be discussed in a general manner. The potential manufacturer operating on a small scale to-day and requiring about 100 short tons of crude gypsum, could obtain this at about 36s. per short ton in Johannesburg. Farmers in the districts of Kimberley and Boshof would be willing to contract at 25s. per short ton f.o.r. for small quantities. It would be more economical for the large manufacturer to do his own quarrying. Under present conditions with a monthly output of 500 to 1,000 short tons, production costs would vary from 14s. to 12s. f.o.r. per short ton, the grade would lie between 80 to 85 per cent. gypsum. In the Van Rhynsdorp district costs may be slightly less; the Natal deposit will be only a little more expensive to work. Calcined gypsum is being landed at our ports at £4 per short ton—this seems to leave the South African manufacturer enough margin to operate profitably, even after allowing for the fact that 1¼ tons of gypsum are required for 1 ton of Plaster of Paris. In my opinion a factory on the Rand would be placed in a strong position but that of the coastal towns is not so strong as here the disadvantages of the railway rate " barrier " are felt.

Definite and up-to-date technical knowledge in calcination as well as in the manufacture of derived products is essential for a successful venture. A capital outlay of about £15,000 will be necessary; the industry will encounter an initial lean period—builders will have to be made to realise the advantages of the more or less new products. This stage was encountered and successfully overcome in such countries as the United States, Canada, Australia and, more recently, New Zealand. In South Africa the building boom makes this a propitious moment for a similar undertaking. There is little present hope for an export trade in such products except to our immediate neighbours.

Gypsum has been produced in South Africa since 1913—practically all of it being absorbed by the cement industry, while negligible amounts are used in agriculture and in the purification

of water. The following are the production figures for crude lump gypsum, the grade of which fluctuates between 65 per cent. and 90 per cent.:—

Year.	*Production.* (Short tons.)	*Value.* £
1913..............	121	484
1914..............	1,791	6,726
1915..............	2,838	8,429
1916..............	3,990	11,983
1917..............	2,082	5,092
1918..............	2,638	6,843
1919..............	?	10,921
1920..............	?	14,098
1921..............	?	8,681
1922..............	?	4,877
1923..............	6,419	9,610
1924..............	10,162	11,868
1925..............	7,978	9,212
1926..............	12,554	14,233
1927..............	17,009	18,478
1928..............	16,393	13,252
1929..............	19,010	14,872
1930..............	18,847	14,817
1931..............	16,366	13,023
1932..............	7,841	6,272
1933..............	13,017	10,108
About.......	180,000	£213,869

The 1934 figure is 25,680 tons—a record.

The figures show that the declared value, and with it the price of locally produced crude gypsum, has fallen steadily ever since production commenced. In 1919 Rindl quoted the price as being £2. 10s. to £2 per short ton f.o.r.—to-day it is about half that.

Import figures of gypsum, burnt and unburnt, are:—

Year.	*Short Tons.*	£
1927..............	603	3,715
1928..............	867	4,538
1929..............	1,168	5,528
1930..............	1,654	5,996
1931..............	2,635	6,359
1932..............	2,293	4,475
1933..............	1,617	6,297

These figures together with the previous ones would make it appear that we are dealing with a relatively unimportant article—but it must be stressed that the uses of gypsum, especially in the building industry, have not been realised in this country, probably because it is not known that large reserves of gypsum await exploitation.

Further, no reliable import figures of manufactured gypsum products can be given.

CHAPTER I.

GYPSUM AND ITS CALCINATION.

The chemical composition of gypsum is given by the formula $CaSO_4 2H_2O$—hydrous calcium sulphate, the constituents giving the following percentages by weight:—

CaO	32·6
SO_3	46·5
H_2O	20·9

It is a common mineral occurring in a number of places in South Africa in the form of crystal aggregates (rosettes) and clear crystals (Selenite) which often exhibit the characteristic " swallow-tail " twins; the sizes seen varied from a few millimetres to about 45 cms. Rarer are vbrous and massive forms. The rosettes are usually clouded in varying degree with clayey matter representing the nucleus around which crystallisation was facilitated.

Gypsum possesses perfect cleavage giving thin plates which are flexible but not elastic. The colour varies with the impurity, which is mainly clay but some may be of organic origin. Grey and pale shades of brown are common while colourless crystals are exceptional. A banded structure has been observed where redeposition had taken place—in such cases there is a tendency towards an acicular habit, in contrast to the tabular one. Massively banked gypsum admixed with clay was also seen on one occasion.

In the Mohs' scale crystalline gypsum furnishes the standard for the second degree of hardness ($H = 2$)—it can be scratched with the finger nail. It lacks the greasy feel that characterises other soft minerals like talc and graphite. Its specific gravity is 2·3, i.e. a cubic foot of gypsum weighs 2·3 times as much as water and would therefore weigh 143·5 lb. The mineral is slightly soluble in water—an important factor if it is to be washed; it has been found that in washing about 20 per cent. of it is lost.

Commercially gypsum is of value because after it has been calcined and then mixed with water, it will set and harden. This property was already utilised 4,000 years ago by the Egyptians. The practice of calcination varies in different mills according to the experience of the operators in getting desired results, the kind of machinery used, and the volume of business. Calcination is completed in some plants in 60 to 75 minutes, in others the gypsum is cooked slowly for three or four hours. When gypsum is dried before going to the " kettle ", calcination is expedited. Some operators believe high temperature for a short time gives the best results, whereas others maintain that a lower temperature for a longer period gives a more even and thorough calcination. In either case the results seem to be the same.

Crushed, not ground, gypsum is carried by belt conveyors to a dryer, a large rotating cylinder, slightly inclined from the horizontal, where the mineral is fed into the upper end and dried by hot

gases entering at the lower end. Then the dry gypsum is pulverised and calcined in "kettles"—in Europe the more common process is calcination in ovens, using lump gypsum, but I believe this old process is more in vogue in France than in Germany. A calcining kettle is a hollow cylinder made of boiler plate, having a convex iron or steel bottom, resting on a masonry fire-box and surrounded by a brick shell. Kettles have a diameter of 8 to 14 feet, a depth of 6 to 10 feet and a capacity of 7 to 20 tons of ground gypsum per charge. They are heated by coal, oil or wood fire applied in a fire-box beneath the kettles. The top is covered by a lid with charging doors, through the centre of which passes a vertical gear-driven shaft carrying at its bottom a cross-arm with stirring paddles. The stirrer is run at about 15 to 20 revolutions per minute and usually requires about 15 to 20 horse-power. The gypsum is fed slowly into the kettle, which is heated to 212° F.; the temperature is gradually raised and at 230° F. the charge begins to boil. This vigorous boiling continues until about 270° F. is reached; then boiling ceases and the whole mass settles down to 10 per cent. to 14 per cent. less than the original volume. This comparatively quiet condition is called the "first settle" and means that most of the gypsum particles are dehydrated to the first stable chemical combination of the half hydrate, $CaSO_4.\frac{1}{2}H_2O$. With increase of temperature boiling recommences at 325° F. and ceases again when the "second settle" is reached at 390° F. At this stage all of the gypsum has been dehydrated to the half-hydrate and some of it has been reduced to soluble anhydrite ($CaSO_4$). The loss from the original volume is now 15 per cent. to 18 per cent. Calcination is stopped before or after the second settle has been reached, depending on the character of product wanted. In making wall plaster the common practice is to stop calcination after the first settle at temperatures ranging from 310° to 350° F. For bedding plate glass, and for purposes requiring a denser and stronger casting, calcining is continued to the second settle.

The time of calcination averages two hours. After calcination the material is discharged through a gate into a fire-proof cooling bin or on to a floor, where it cools. Next it must be screened to remove the coarse lumps, which are reground. A shaking or tapping screen is preferred to a rotating screen for classifying gypsum at any stage in its manipulation on account of the ease with which the screen clogs or gums up.

A rotary-kiln known as the Cummer process is also used. Gypsum crushed to about $\frac{3}{4}$ inch is fed into a rotary-kiln about 5 feet in diameter by 30 feet or more in length, in which a temperature of 400° to 600° F. is maintained. In a 30-foot kiln about 10 minutes is required for material to pass through. Upon discharge it is not wholly cooked, but is still steaming and is placed in one of four brick-lined bins for 36 hours, where the dehydration is completed. By using the four bins alternately, continuous operation is possible. If kilns as long as 70 feet are used, the calcination may be completed in the kiln and the bins can be dispensed with. The rotary kiln product is then ground fine. This grinding is done in burr mills, disintegrators and so on.

The calcined product at this stage is known as stucco or Plaster of Paris and has an ideal composition of $CaSO_4 . \frac{1}{2}H_2O$ (about 94 per cent. $CaSO_4$ and 6 per cent. water). When pure and ground to 80 per cent. to 90 per cent. through 100 mesh, it starts to set in 6 to 10 minutes.

In order to control the rate of setting, accelerators or retarders must be thoroughly mixed with the plaster. The action of these seems to be mechanical, in that they hinder or help the crystallisation of the gypsum. Retarders are usually dispersing or deflocculating agents and accelerators are coagulating or settling agents. As retarders, organic materials such as glue, glycerine, flour, blood and sugar are commonly used. From 2 to 15 lb. of retarder per ton of plaster is commonly used. Practically all gypsum wall plaster is retarded so that when mixed with two parts of sand by weight it will set in about 2 hours. By the addition of alum or other inorganic salts to fine white plaster, the time of set may be reduced from 6 to 3 minutes. This is done principally in making dental plaster. Some impure plaster is accelerated by using common salt.

Fillers such as hair, wood fibres, sand, hydrated lime, talc, etc., may be added to stucco to make special types of plasters. These fillers, together with the accelerators or retarders are added to the stucco in proper proportions in a batch-mixing machine. From this machine the finished plaster drops into a hopper, from which it is bagged for shipment.

CHAPTER II.

THE USES OF GYPSUM.

A. Raw or Uncalcined Gypsum.

(1) *Retarder in the Manufacture of Portland Cement.*

Gypsum is universally used as the retarding element in Portland cement. Cement should not develop its initial set in less than 45 minutes, nor its final set in less than 10 hours (Amer. Soc. for Testing Materials, Standards, 1918). The finer the cement is ground the more gypsum is required to prevent it setting too quickly. The action of the gypsum is not properly understood. Standard specification limits the proportion in the U.S.A. to 4·3 per cent. gypsum; further addition is injurious. Raw gypsum crushed to about $\frac{1}{2}$ inch is added usually in proportions of 2 to $2\frac{1}{2}$ per cent. to the cement clinker as it comes from the roaster before it is ground.

Nearly all the gypsum produced in South Africa is used in this way. The consumption for this purpose will rise appreciably with the expansion of the cement industry, which can be expected in the next few years.

(2) *Gypsum in Agriculture.*

I am indebted to Dr. St. C. O. Sinclair, Chief of Division of Chemistry of the Department of Agriculture, for the following remarks on the uses of gypsum in agriculture:—

> " Raw ground gypsum applied to some soils may have a very beneficial effect. The main action of gypsum is that of a soil improver and it can hardly be regarded as a fertiliser, i.e. a supplier of food for plants. However, under certain conditions it may indirectly supply potash for plant food by its action on the double silicate of magnesia and potash (felspar) present in the soil.
>
> " In this country gypsum could be used to some extent as a corrective on certain alkaline or ' brak ' soils. It owes its efficacy to its power of converting sodium carbonate into the less injurious sodium sulphate. For this treatment to be successful it is further necessary to have sufficient water of a suitable composition available to allow of the leaching of the soluble salts.
>
> " Brackness is due to the presence of alkaline salts—comprising the chloride, sulphate and carbonate of sodium. Considerable variations occur in respect of total amount and relative proportion. Of these salts sodium sulphate is the least injurious whereas the carbonate is usually held to be the most harmful. Before an attempt is made to reclaim a brak soil, expert analyses must be made; for if there is only very little or no sodium carbonate present the addition of gypsum would be useless. Brak soils containing an appreciable amount of sodium carbonate are usually extremely impervious to water and intractable to work, on account of the deflocculated condition of the clay particles. If the carbonate has interacted with the gypsum the soil becomes flocculated and can now be penetrated by water. Excessive salts can therefore be leached from the soil and the degree of brak considerably reduced.
>
> " It is possible that with the accumulation of reliable practical and experimental data on the use of gypsum on brak soils under South African farming conditions, a fair demand for agricultural gypsum might result ".

A number of further claims are listed elsewhere, e.g. see Chapter X, " Gypsum, its occurrence, origin, technology and uses ", *Geol. Surv., Iowa,* Vol. XXVIII, but these have still to be proved for this country, where, in the words of the covering letter of Dr. Sinclair, " very little experimental work has been conducted ".

One use, mentioned in the publication cited above, and also by Stone, may be quoted in his own words: " Raw ground gypsum or land plaster, if applied freely on manure piles and stable litter, acts as a disinfectant and also retains the ammonia, which is the valuable product of the barnyard manure heap. Gypsum reacts with the ammonia of the manure to form ammonium sulphate. This easily available plant food thereby is not given off into the air nor is it readily washed from the heap by rain, but is saved until the manure is spread on the land ".

With an increase of our information regarding the suitability of gypsum in agriculture in this country, and with the low costs operative in comparatively large scale production a satisfactory market may yet be found for agricultural gypsum.

(3) *Treatment of Water.*

Gypsum is used in South Africa for purifying turbid waters. In 1926, 3½ million gallons of water were so treated daily—mainly at Bloemfontein and Kimberley. Since then the quantity has increased. Approximately 1,000,000 gallons a day require for treatment 110 tons of gypsum per annum. In 1926 the cost of treating 1,000,000 gallons in this manner was £1. 10s. Proposed plants in that year provided for the purification of a further 4 million gallons a day—the demand for this use of gypsum will hardly attain major significance commercially, but it is important enough to merit attention.

Gypsum is added to some waters used for brewing, as it increases the solubility of the albuminous matter in the malt.

(4) *Crayons.*

The common black-board or school crayon known as chalk is usually made of pulverised gypsum. Ingredients added include a binder and for coloured crayons a pigment. The mixture is moulded into the required shape under pressure.

(5) *Flux.*

Gypsum is used as a flux in certain metallurgical processes of some nickel and lead ores.

(6) *Terra Alba.*

Very white gypsum which has been ground and bolted through a 200 mesh screen is sold as a filler for paper and paint under the name of terra alba. In the making of paper its function is to close the pores and permit of a hard finish.

(7) *Insecticides.*

Finely ground raw gypsum as well as calcined gypsum is used to dilute arsenic poisons that are used in combating insects. It acts as a splendid carrier for the concentrated insecticides such as arsenate of lead, Paris green, nicotine sulphate, calcium arsenate and others.

B. Calcined Gypsum.

Gypsum partly dehydrated or calcined and pulverised is called Plaster of Paris or stucco. This product can be put to many uses and, by the addition of other substances to control the plasticity and the time of setting, its range of usefulness is greatly increased. In recent years the development of plaster boards and tiles and blocks has increased enormously. Our raw materials should prove satisfactory for the utilisation of the undermentioned building materials.

(1) *Wall Plaster.*

The principal use of calcined gypsum, amounting in U.S.A. to about a million and a half tons annually, is as wall plaster. It can be noted here that even if much of the South African burnt gypsum should show a faint coloration, this does not condemn it, as dyes are often added to produce the soft shades in vogue to-day—alternately, a coat of paint is administered. All gypsum plasters have other materials added to the calcined gypsum either before sacking or just before wetting for use. These plasters are commonly known as "hard wall plasters". They are used in the ordinary manner for covering walls and ceilings. Some of the advantages of these plasters are:—

High tensile and compressive strength combined with light weight; great resistance to shock and wear (gypsum plaster used in the buildings of Egypt is still in a good state of preservation to-day); setting and drying take place quickly, thereby lowering costs; permanency of decorations (paints) on gypsum plasters because they are chemically inert; their smooth and non-porous surfaces mitigate against vermin or germs establishing themselves; great resistance to fire; very useful for soundproof structures and in overcoming acoustic difficulties. Acoustic plasters claiming a sound absorption coefficient of 20 per cent. are on the market; with the advent of the sound-film their demand must have grown enormously. Because it is a poor conductor of heat and cold, the plasters find application as an insulating medium in cold storage buildings and as a covering for heating plants and water pipes. Similarly it is used for fire protection of steel frames of buildings by surrounding the members to be protected.

(2) *Gypsum Plaster Boards.*

These are of various types, consisting of stucco mixed with fibrous building material which should not exceed 10 per cent. by weight and which is added to give strength and toughness for effective nailing. The boards should not be less than ⅜ inch thick. Alternate layers of felt or paper are sometimes used—I have been informed that a factory in Capetown is using asbestos fibre. Possibly the sugar cane fibre could also be utilised.

Plaster boards are used in place of wood or metal lath, on surfaces that are to be plastered and where high fire resistive construction is required. They are used for deadening sound by being laid between floors and are desirable material for improving the acoustics in a building.

(3) *Gypsum Wall Boards.*

These are similar to plaster boards but they give a finished wall when nailheads and cracks are covered by wooden strips or otherwise concealed—they are not intended to serve as a base for plaster. Gypsum wall board has fire resisting features. It will not burn even at high temperatures and is capable of withstanding great heat for a long time without breaking down. It thus presents an effective barrier to the spreading fire. It does not shrink, expand, warp or buckle, and for all situations where a type of construction more flexible than a plastered surface is desired, it probably offers greater

advantages than any other form of construction material. It may be applied and decorated in the same way that any of the numerous forms of wall boards are treated.

(4) *Gypsum Blocks and Tiles.*

These are solid or hollow, 12 to 30 inches wide and 2 to 8 inches thick. They are made for partitions, floors, roofs and furring. These blocks and tiles, laid with gypsum plaster, are used in the highest type of fireproof building; they have 40 per cent. greater resistance to heat conduction than other standard materials. They are light in weight, being 30 per cent. to 35 per cent. lighter per square foot than any other structural material of a similar nature. They can be laid rapidly, can be cut with a handsaw, and they are 60 per cent. more effective as a non-conductor of sound than other types of standard partition material and may therefore be commended for hotels, apartment houses and educational institutions. In roof-construction this sort of tile has many especial advantages, e.g. saving in dead weight, sound absorption and damp-proofing.

(5) *Hydraulic Gypsum, Keene's, Mack's and Parian Cements.*

Above 190° C. gypsum is completely dehydrated and loses its property of setting. It is then said to be "dead-burnt". If heated to a temperature exceeding 500° C. the calcium sulphate (i.e. the dead-burnt) becomes hydraulic. This hydraulic gypsum is known in Germany as "Estrich"; it is produced with the temperature around 900° C. It is often used for flooring.

Keene's cement as originally made in England was produced by calcining lump gypsum to produce the hemi-hydrate, soaking the lumps in a solution of alum, aluminium sulphate or borax, recalcining at 500° C., after which the lumps were ground. Various modifications of this method are employed by different manufacturers. When borax is used the product is called Parian Cement. Keene's cement may be classed as a superior Plaster of Paris in that it is much harder when set, although it takes longer to harden. It makes a good finishing plaster. It is especially suitable for moulding, the sharpness of the casting made from it being due to the slight expansion of the material during the process of setting. Because of its superior hardness, walls covered with it suffer with regard to acoustics. In addition to its greater hardness Keene's Cement is valued because it takes a high polish and will to some extent withstand the exposure to the elements. Mack's Cement consists of hydraulic gypsum to which 0·4 per cent. of sodium sulphate or potassium sulphate has been added. This cement is unusually hard and durable, sets quickly and bonds well with the background to which it is applied.

(6) *Miscellaneous Uses.*

Plaster of Paris is used in the preparation of dental plasters and surgical casts. It is used in modelling and for moulds in the pottery trade, in the glass industry, in foundries and in the manufacture of architectural terra-cotta. Calcined gypsum enters into the composition of match-heads and hat-blocks; it is used for various other purposes too numerous to be listed here.

CHAPTER III.

DESCRIPTION OF SOUTH AFRICAN GYPSUM DEPOSITS WITH A VIEW TO THEIR EXPLOITATION.

A. Minor Occurrences.

1. *Namaqualand.*

At Port Nolloth, about half a mile from the coast and parallel to it, is a pan more or less surrounded by sand-dunes. The pan is 1½ miles long with a width of 400 yards, which increases to about 750 yards at its northern end. Doubtless this is a shallow arm of the sea which has been cut off by the drifting sand. A grey sandy saline overburden covers the greenish clay in which the gypsum occurs in large slabs of crystal aggregates or as flat almost circular crystals, commonly 6 inches in diameter. The clay is occasionally sandy and even gritty. The total thickness of the sediments in the pan does not exceed 4½ feet—the edges are even shallower.

The gypsum is of excellent quality, and occurs 1 to 2 feet below the surface of the pan. Unfortunately the deposit of this type of gypsum is confined to a portion of the western edge of the pan. Much of the material has been taken out and used as road metal. A few thousand tons may still be available. A little clay and probably some sand are included in the crystals.

The sandy surface material doubtless carries much gypsum as minute crystals—no chemical analyses are available to verify this. Ill-defined thin layers of small crystals, about 1 to 2 inches in diameter, often with a brown coloration, occur in the clay layer of the pan at different depths—these are of no economic value; nor are the peculiar irregular pockets (3 to 6 inches) of pure loose gypsum crystals workable. These pockets occur about 6 inches below the pan's surface and are not frequent. The crystals are 2 to 3 mm. in diameter and quite dry. Summing up, there is a limited amount of excellent gypsum available—exploitation except for local use or an occasional shipment is highly improbable.

2. *Kimberley District.*

About 1½ miles from Riverton Station (Cape) on the farm *Zoutpansfontein* is a saltpan which is worked by the Nantwich Salt Works who produce a very pure salt here. Riverton Station is 16 miles north of Kimberley. On the surface of the dry (southern) portion of the pan and also admixed with the clay to a depth of a few feet, "granular gypsum" occurs in the shape of small flat grey crystals a few millimetres in diameter—similar to those found in pockets at Port Nolloth, but lacking that sugary whiteness found there. Possibly irregular layers of larger crystals may be found at depth—no adequate prospecting has been carried out. Quantities of about 10 tons or so of the gypsum at the surface, after having been wind-cleaned, are occasionally collected to satisfy a small demand of the nearby waterworks.

No representative analyses are available, although Rindl mentions a grade of 82-84 per cent., for the wind-cleaned material. I have been told that a higher grade could easily be obtained. The gypsum is

greyish and the chief impurity is clay—wind-blown sand must further contaminate this gypsum, especially in the small gypsum dunes forming in the southern extremity of the pan: the prevailing wind blows here from the north-west.

Production of gypsum is largely dependent on the weather. The low rainfall, and the frequent winds which break up the thin crust on the surface into a powder and free the crystals from the bulk of the clay, facilitate the collection of the gypsum. The tonnage that could be produced may run into a thousand tons or so a year—nothing definite can be predicted. Nor can the reserves available be estimated as it is very likely that in the dry seasons a new " crop " of crystals is deposited along with the gypsum dissolved during the rains.

The Nantwich Salt Works, Ltd., of Kimberley are anxious to extend their market for gypsum. This type of gypsum should be advantageous for particular uses.

3. *Hay District.*

The best quality gypsum in South Africa is found as large crystals in the grey clay of the vegetation-less pan on the farm *Saltpan*, in the district of Hay. The owner is Mr. G. G. K. Schmidt, and his son Mr. R. F. Schmidt is in occupation. The latter produces 300 tons of salt per annum. The most convenient railway station is Silver Streams (line Kimberley-Postmasburg), 94 miles west of Kimberley.

Underneath an overburden of 5 to 6 feet of sandy, grey clay which carries small crystals and sometimes small workable stringers of gypsum, the first horizon of gypsum with colourless crystals is reached. The crystals are smaller than those of the succeeding layers which are separated by about one foot of light grey clay; this clay when moist is like putty except that it is more tenacious. There are four more or less continuous, thin layers in all—towards the sides of the pan they peter out. The crystals in the lower three layers are tinged light brown and sizes of 6 inches are common. In the fourth layer crystal-aggregates in ill-defined cakes or slabs are characteristic, while in the second and third, large isolated tabular crystals are typical. The lowest layer is 8 to 9 feet below the pan's surface—towards the sides of the pan this depth is less. At about 10 feet the clay seems to end and a thin irregular bed of flint and some sub-angular quartz appears to rest on solid or fragmentary cream-coloured limestone—similar to that found on the surface in the vicinity.

The gypsum is exceedingly pure. Costs of production are considerably increased due to the difficulty in removing the clay—even a strong jet of water failed to give satisfactory results. At present the gypsum is laboriously cleaned with ordinary scrubbing brushes. The point arises whether a small percentage of impure amorphous carbonate of lime, for that is the composition of the earthy matrix, is not permissible as an adulterant in most cases. No analyses of the gypsum in bulk have been made, but it appears certain that a 95 per cent. grade can be supplied without much difficulty—possibly the grade may be higher.

The deposit is limited, however; a reserve of at least 6,000 tons exists—possibly it may total 10,000 tons, but the pan is not capable of supplying more.

B. Major Occurrences.

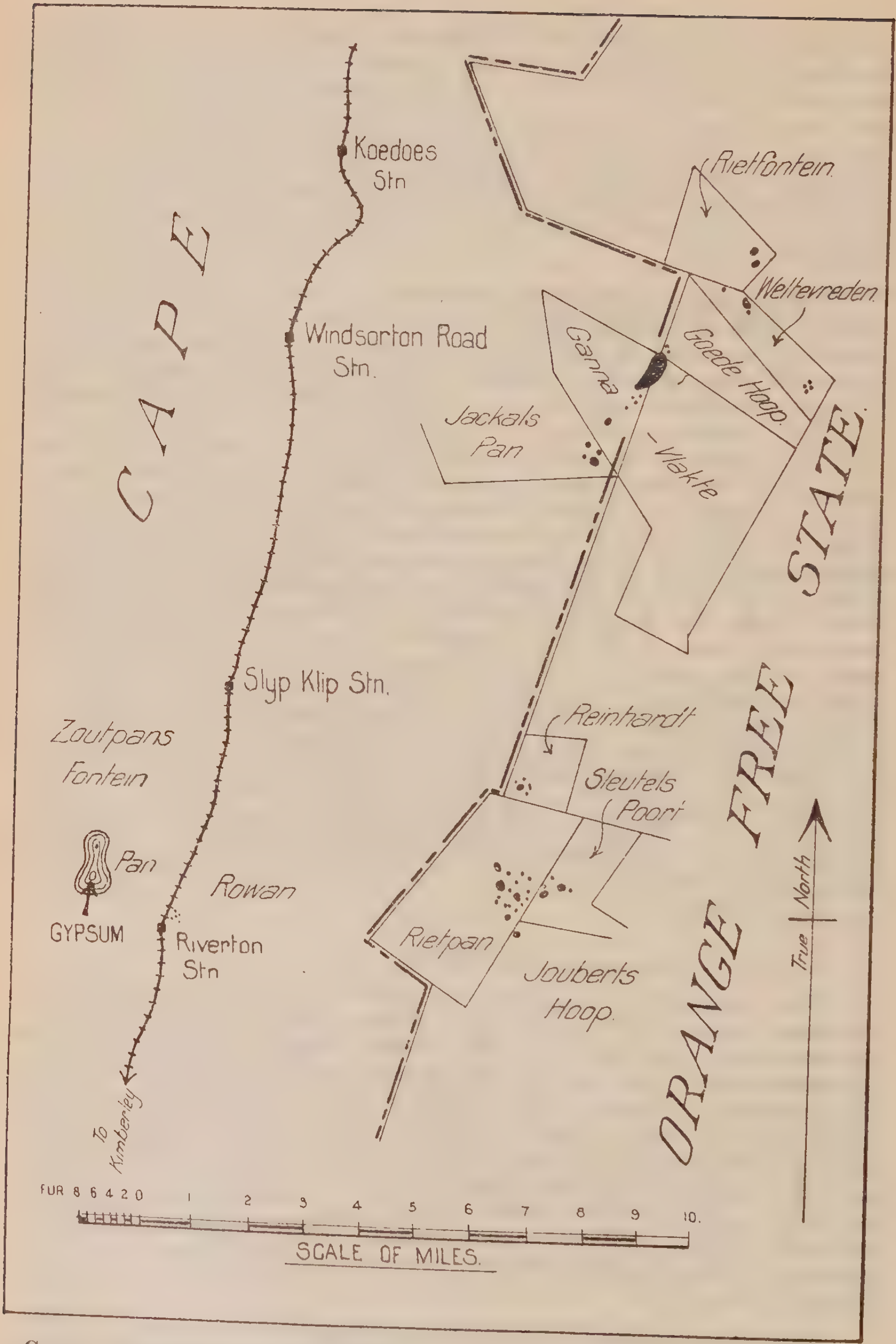
The gypsum of the above three occurrences differs from that found in the major deposits of this country. These deposits with a tonnage running into millions lie in the districts of Kimberley, Boshof and Van Rhynsdorp with a smaller deposit in the Umsinga Native Reserve. They can easily and economically be worked. The mineral occurs as nodular lumps, i.e. crystal-aggregates disseminated through clay which constitutes the chief impurity; small amounts of clay are included in the crystals and this gives them a pale brownish, grey or pink coloration.

The gypsum-clay has an overburden of 2 to 4 feet. The lumps, varying from an inch to a foot in diameter are dug out with pick and shovel by natives. These are paid from 4s. to 8s. for the cleaned ton—tools being provided. A good boy earns £5 to £6 a month. Only a rough cleaning is carried out; the clay content is reduced in order to save in transport charges. The gypsum is left in heaps for a few days to be dried of its small amount of moisture by the wind. When dry most of the clay in the interstices of the lamps falls away easily in being sieved in "babies"—this sieving is repeated three times. There is much loss of gypsum in the "fines"—the bulk of the gypsum sent away in bags to the nearest railway station is in lumps from 2 to 5 inches in diameter. In the Van Rhynsdorp area a few blows with the hammer, whereby the lumps are broken into convenient sizes, is the sole method of cleaning employed and the grade of the present producer is around 85 per cent. gypsum. It must be mentioned that there are minor variations in grade of deposits from place to place—a more important factor in obtainng a high grade is the aptitude of the individual native. A former producer saved the fraction around ¾ inch diameter from his "fines" which he said gave a grade of over 90 per cent. gypsum. The possibilities of cleaning gypsum by sieving alone have not been exhausted yet. The demand will determine the grade. In Australia the grade of the raw material is 95 per cent.—in the U.S.A. it is somewhat higher.

(1) *Districts of Boshof and Kimberley.*

The largest producer of crude gypsum in South Africa is the Pretoria Portland Cement Co., whose workings on the farm *Gannavlakte,* 7 miles from Windsorton Road Station, district of Kimberley, account for over 80 per cent. of the total production in this country. The workings cross the Cape-O.F.S. boundary to the farm *Raadsbesluit,* district Boshof, O.F.S. The grade in bulk averages 80 per cent. gypsum—no serious effort being made to obtain a higher grade as the clay impurity is not injurious in the cement industry. Truckloads occasionally average a 90 per cent. gypsum content. Nearly 120,000 short tons of crude gypsum have been produced here and the reserves in sight are half a million tons of 80 per cent. ore.

The workings are in the low-lying, though not the lowest, portion of the farm, the slope of the ground being almost imperceptible. These deposits together with those on the nearby farms lie more or less in a line running N.N.E.-S.S.W., parallel to the long axis of a



Gypsum Quarries and Pits along the Cape-Orange Free State Boundary.

shallow grass-covered depression or wide drainage channel which has cut through a thin dolerite sheet, the western edge of which is close to the workings, about $1\frac{1}{4}$ miles. The removal of the dolerite has allowed the gypsum to form in the underlying Upper Dwyka Shales, which lie under a recent overburden. A profile is given by:—

Horizon 1:	Overburden..................	$2\frac{1}{2}$ to $4\frac{1}{2}$ feet.
Horizon 2:	Pink to brown clay.............	1 to 2 feet.
Horizon 3:	Light brown to grey clay.......	2 to 5 feet.
Horizon 4:	Dark clay and shale............	—

The overburden is a rich brown sandy loam with its surface a light brown colour and strewn with lydianite pebbles which resemble artefacts to a remarkable degree. The lower limit is sharply defined.

The clays in the other horizons have resulted from the weathering of the shales (Upper Dwyka). There is no sharp demarcation between the various horizons; the clay passes into the broken-up shale which assumes a more regular habit with increasing depth. The gypsum makes its first appearance at the top of horizon 2 in spots of minute crystals—the size increasing downwards so that in the lower portion workable lumps of gypsum occur. The lumps and crystals are of smaller dimensions than in the succeeding clay layer of horizon 3 which constitutes the principal source of gypsum. The lumps, usually about 6 inches in diameter and of irregular shape, are indiscriminately scattered through the rather friable mottled clay, but become rarer with depth in the fourth horizon which, however, is sometimes workable for a few feet.

In the clay thin lenses of lydianite pebbles and boulders—rarely isolated—are occasionally met with; cream coloured limestone, nodular or in thin banks, are not uncommon. A thin narrow purplish band, probably due to concentration of iron and manganese oxides along a favourable plane, is encountered in some pits.

Deposits almost identical with that described lie in the northern and southern continuance of the shallow elongated depression already alluded to, giving a series of discontinuous deposits over a length of about 13 miles. The variation in altitude of the deposits is roughly 50 feet. Minor variations in grade evidently exist but in the absence of chemical analyses nothing definite can be said. Similarly, differences in the thickness of the overburden and in the payable depths are met with, but such modifications are not marked or sustained enough to warrant classification. These deposits can be regarded of a single type as regards mode of formation and workability.

Before the Cement Company acquired its own workings, the farms mentioned below were producers—they shut down in 1925. Prospecting pits and quarries have mostly been filled in to safeguard livestock; this procedure has aggravated the difficulty in arriving at estimates of the reserves as the gypsum does not outcrop.

The farms *Goede Hoop*, *Weltevreden*, *Rietfontein No.* 819, carry the gypsum belt northwards, while in the south there are the farms *Jaskals Pan*, *Reinhardt*, *Rietpan* and *Sleutels Poort*. This list may be incomplete—there is no incentive to prospecting just now.

Goede Hoop adjoins Gannavlakte, and a number of tons were extracted close to the latter's workings until 10 years ago. No adequate prospecting has been carried out; 20,000 short tons of gypsum ore are available around the abandoned quarry—future prospecting may reveal appreciably more.

Weltevreden adjoins the previous farm. The large fallen-in workings and old prospecting pits in the north-western portion of the farm reveal 40,000 short tons of ore in sight—the reserves will prove to be larger once prospecting is systematically carried out. In the south-eastern part of the farm, meerkat holes indicate that gypsum occurs over several morgen of ground. In the absence of any exact data, it may be assumed by analogy that the tonnage available on this farm is of the magnitude of 100,000 short tons of ore—probably this is a very conservative figure.

Rietfontein No. 819 lies to the north of Weltevreden and was a large producer for 7 years; at one time production was 350 tons a month. The owner claims to have proved about 200 morgen of gypsum ground; this would represent a reserve of at least 1 million short tons of ore; this estimate is probably exaggerated. There is every indication suggesting a very large potential reserve; if, as is believed, the gypsum is continuous between the former workings, 100,000 short tons of ore would be available—and this would not represent the total reserves. In all probability the magnitude of the deposit is nearer a quarter of a million tons.

The gypsum-clay face is said here to average 14 feet below an overburden of only 2 feet. If this be so, the rough estimates given are extremely low.

Jackal's Pan, district Kimberley, adjoins Gannavlakte in the south and was a producer until 1928. The workings are in a straight line with, and lie south-west of, those of Gannavlakte, representing their continuation. It is considered that 120,000 short tons of ore are in sight and that this is but a fraction of what will be proved by systematic prospecting.

Reinhardt No. 936, about 4 miles south of the previous farm, produced for 2 years and shut down in 1929. The overburden is about 3 feet. Information was obtained that the deposit is workable to a depth of 22 feet—but it is not known whether the deposit could be economically worked at that depth. The writer was shown some remarkably pure slab-like gypsum which is supposed to occur at such depths. Neglecting the possibility of increased tonnage with exploitation at greater depths, there appears to be 50,000 short tons of ore reserves in sight—with a probable upper limit around 200,000 tons.

On this farm Glauber Salts ($NaSO_4 10H_2O$) and Epsom Salts ($MgSO_4 7H_2O$), together with a little common salt, are sometimes collected in large lumps of loose crystal aggregates in the cold mornings of the winter.

Rietpan No. 1389, immediately south of the above farm, possesses the largest proved deposit, which continues on *Sleutels Poort* and in a small way on *Jouberts Hoop*. The deposits are

probably richer than on most other farms as the natives doing piece-work, had no difficulty in extracting higher tonnages per month individually.

The overburden varies from $1\frac{1}{2}$ to 3 feet and the total depth reached in the quarry is usually 8 to 9 feet. Conservatively the reserves in sight are almost $1\frac{1}{2}$ million short tons of ore; this includes nearly $\frac{1}{2}$ million tons lying in a strip of the farm belonging to the owner's brother-in-law.

Sleutels Poort, lies just east of Rietpan and on it the deposit continues. The reserves in sight here, determined by prospecting, are close to 900,000 short tons of ore.

Rowan is situated at the Riverton railway station. This farm falls outside the belt just described, but is only 6 miles away from Rietpan and not 2 miles away from the pan on Zoutpansfontein. The gypsum lumps seen here were smaller and more fragile than those of the deposits mentioned above—possibly they were from the upper portion of the gypsum horizon only and not representative of the deposit as a whole; this gypsum occurrence may yet prove to be similar to the others. No information of the grade is available. An analysis shown to the writer gave 86·5 per cent. gypsum and an insoluble residue, which was mainly clay, of 8·8 per cent.

An attempt at prospecting has been made by the owner but the pits were mostly filled when the farm was visited. From information received and from the little seen on the ground it is very likely that a deposit of 50,000 short tons could be proved. The fact that this deposit is on the railway merits attention.

Kleinboschvarkfontein, which was a producer many years ago, is about 22 miles east of Kimberley, but it is only 4 miles from Bosvark Siding (line Kimberley-Bloemfontein). Reserves in sight are about 50,000 short tons of ore—the deposit will be proved larger when prospecting has been carried out. It continues on to the adjoining farm Boschvarkfontein. The writer considers this area a fruitful one which would repay prospecting, especially in view of the proximity of the railway.

Vrede is one of the early discoveries and has therefore been repeatedly cited in technical literature. With our present knowledge, this farm, which is roughly 40 miles from the railway, will hardly be able to compete against the more favourably situated deposits—unless the high grade claimed, namely, over 90 per cent. gypsum after only rough cleaning, cannot be attained by the other producers. The deposits are 17 miles south-east of Boshof. It is stated that an area exceeding 400 acres of gypsum-bearing ground has been proved—this would mean a reserve of one million short tons of ore. This may be the case; ore in sight at the time of my visit was over 30,000 short tons. Similar deposits on nearby farms await discovery.

(2) *District of Van Rhynsdorp.*

The deposits of gypsum in this district are similar to those of the districts of Boshof and Kimberley and are worked in the same way. Geologically they present some modifications not encountered in the previously mentioned occurrences and accordingly there appears to be a greater variation in grade from place to place. The country

is not quite so flat here—soft undulations and occasional low hills are characteristic. The workings are usually in the upper portion of a gentle slope bordering a shallow drainage channel whose tributary short spruits and dongas have revealed the deposits to the prospector. The location of the workings and their development along the contours of the slopes, suggest that the deposits do not extend far at right-angles to these contours. This view was supported by the few prospectors in the area. Again, lack of prospecting results intensify the difficulty in arriving at an even rough estimate of the available tonnage; but it must be admitted that the prospector so far has been given no particular inducement for collecting such data.

The overburden which is not of a uniform nature, lies between 2 to 4 feet in thickness; the total depth reached in the workings is about 7 feet. The roads here are generally worse than in the other districts mentioned; lorries are being used for transport while at the workings of the Pretoria Portland Cement Co., at Gannavlakte, donkey-wagons, doing a return trip a day, are considered more economical. As gypsum occurrences are frequent in this district, some farmers dig small pits to obtain the mineral which they use as a fertiliser.

Aties.—This farm has been sub-divided and the workings are on Onder-Aties. They are 10 miles north of Klaver which is on the railway line Capetown-Bitterfontein. The overburden is about three feet of windblown red-brown sand and some sporadic surface limestone. The grade is said to vary from 60 to 80 per cent. gypsum after rough cleaning. Some of the gypsum has formed in graphitic-rich zones and is black or almost so. Occasionally thin compact gypsum layers of small extent are found interbedded in the weathered schistose rocks which have furnished the clays.

No estimate of tonnage can be given but the workings have produced at the rate of 350 short tons of about 75 per cent. ore a month—very likely they could continue at that rate for a number of years.

Gordon's Hope.—This base mineral lease includes gypsum ground about a mile from Holrivier Siding which is 27 miles north of Klaver. Several small workings and pits have been started. Lack of uniformity in grade, clay and overburden is observed at different points. In one place the gypsum appears to occur in the overburden whose lower boundary is ill-defined. In the south-eastern portion of the claim 10,000 short tons of good gypsum ore are available in a continuous banked seam. A certain amount of haphazard prospecting has been done revealing a reserve of at least 50,000 short tons of ore—if continuity of the gypsum occurrences in this area should be proved, a very large quantity would become available—as long as the overburden allows of profitable extraction. The overburden is often very thin, but on the other hand large portions of the area are covered by a thick covering of wind-blown sand. This area in capable hands should become a profitable producer once it finds an outlet.

Holrivier.—The deposits are about 3 miles from Liebendal Siding which is 4 miles south of Holrivier Siding. The peculiarity found in most of the overburden is a gravel with some unworkable gypsum

which is in the process of cementing the pebbles. A profile here gave:—

4 ft. ... ... Gravel overburden.
1¼ ft. ... ... Brown sandy gypsum layer.
2 ft. ... ... White to cream, mottled gypsum clay

The bottom of the lowest zone was not seen here—it may continue for about 2 feet. In none of the deposits of this district was the bottom of the gypsum-clay visible. Nothing can be said of tonnage or grade.

Berg Plaats.—Mr. Trytsman's Holdings are on a portion of the farm Berg Plaats and about 11 miles north-east of Holrivier Siding. He has recently secured the contract to supply the Cape Portland Cement Co. (near Piquetberg) and is at the time of writing the only producer in the Van Rhynsdorp district. The grade, after very elementary cleaning, viz. a blow or two with the hammer on the sun-dried lumps, is about 85 per cent. gypsum. Here and there acicular gypsum due to recrystallisation occurs in remarkably pure needles 3 inches in length; recrystallisation has sometimes enlarged the lumps into irregular seams or lenses with an improvement in grade. Some massive cream-coloured gypsum was also observed.

The aeolian, light-brown overburden is usually 1 to 3 feet thick; occasionally it is a foot or so more, and then the productive clay appears richer. The gypsum-clay is greenish-grey with a sporadic red to pink mottling. Isolated sub-angular quartz-pebbles can sometimes be found in the clay. Quarrying extends to a depth of about 7 feet.

The ore in sight is roughly 65,000 short tons with the grade over 80 per cent.; it is easily possible that the reserves here will be found to total 150,000 short tons. The large amount of comparatively high-grade ore is noteworthy.

Blanco.—This locality, listed as a former producer, was not visited. It is possibly a portion of Holrivier.

(3) *Natal.*

Ngobevu.—At this point in the Umsinga Native Reserve, near the junction of the Tugela and Buffalo Rivers and about 25 miles from the Greytown-Kranskop railway line, is situated the only known workable gypsum deposit in Natal. The distance by rail would be about 160 miles to Durban and 550 miles to the Rand. Exploitation by the Natal Gypsum Co., ceased in 1920 after nearly 12,000 tons had been produced; at this time the railway had not proceeded beyond Greytown which is 36 miles from Ngobevu. The rights to the deposit are at present held by Mr. H. J. Horning, a sand contractor at Pietermaritzburg.

Very little of the deposit can be seen now, but it has been described by Hatch, Wybergh and du Toit. I am also indebted for information to Mr. Hedges, a retired mining commissioner who visited the quarries when they were in operation. This deposit does not differ materially from those of the districts of Boshof, Kimberley and Van Rhynsdorp. The rich brown overburden, which carries a thorny vegetation, is 1 to 2 feet thick and carries small gypsum crystals in its lower portion. Beneath is at first a mottled red-blue clay which soon passes into a greyish-blue one. The gypsum lumps

are disseminated through the clay in larger and more compact crystal aggregates than in the other similar deposits visited—this may, however, only hold for the upper part of the productive clay as no deep sections were seen and du Toit mentions that the quantity falls rapidly with depth. The deposit was worked to about 10 feet but the gypsum extends deeper.

The writer considers that a good quality lump gypsum, probably better than that quarried elsewhere, is obtainable here—and the proximity of a perennial stream, the Tugela River, further enhances the possibilities of a high grade if the material is washed.

The ore in sight is in the neighbourhood of 35,000 short tons, but the reserves are very likely over 100,000 tons—prospecting will doubtless prove that this deposit is large enough to merit greater attention and further deposits may yet be discovered in the neighbourhood. With a regular market for about 200 tons a month in Pietermaritzburg or Durban, and with the low wages which exist in this locality, a good proposition for the small worker exists. Should the reserves prove as large as is anticipated, the deposit due to its good grade will probably extend its market as far as the Rand.

(4) *Other Areas.*

In the district of Laingsburg are a number of gypsum occurrences, following the outcrop of the " White Band " of the Upper Dwyka, " confined to the surface and the immediately underlying ground, where, under favourable conditions of contour, considerable quantities may accumulate " (Rogers)*. On Dwars-in-de-Weg gypsum was produced. These occurrences have since proved uneconomical. A similar position is met with in the Prince Albert district.

This completes the list of past and present gypsum producing localities, as far as our knowledge goes. Even conservative estimates of our known gypsum reserves show that if our production of crude gypsum were doubled there would still be a life of nearly 100 years. It is confidently expected that the estimates given here, conservative because of the difficulties encountered in their assessment, will be exceeded by 100 per cent. once the localities mentioned have been systematically prospected. Further deposits of economic worth are bound to be discovered once there is an inducement to prospecting.

A number of pans, usually salt-pans, are known to contain gypsum: the coastal ones around Port Nolloth and in the Van Rhynsdorp district; the inland ones mainly confined to the outcrop of the Upper Dwyka shales in the districts of Calvinia, Carnarvon, Prieska, Kenhardt, etc.—the payable deposits of the districts of Kimberley and Boshof fall into this group. The gypsum is said to continue as far as Kroonstad. This tremendous belt includes a number of known poor deposits comparable with those of the Laingsburg district; of others nothing is known, except that the most are too far from the railway or a possible market to warrant attention in the near future. The conspicuous geological horizon of the Upper Dwyka, the " White Band ", owes its white colour on weathering partly to the formation of gypsum. Some inland pans, e.g. on Heeren Logement, occur in the Van Rhysndorp district as well as in the

* Explanation of Cape Sheet No. 5 (Laingsburg). Government Printing and Stationery Office, Pretoria, 1925, p. 17.

adjoining district of Clanwilliam; in these districts gypsum is occasionally seen in the soil. Dr. Lombaard has informed me that he knew of Selenite twins occurring in the soil in the Zeerust area. Near Port Elizabeth the Zwartkops Pan and the Bethelsdorp Pan which furnish salt contain gypsum and there seems a possibility that it may yet be collected from them. Kynaston* mentions the occurrence of gypsum in the black alluvial soil on the farm Haakdoornfontein near Pienaars River, Transvaal.

Fibrous gypsum, which is remarkably pure but is unlikely to be of economic worth due to its mode of occurrence, viz. in thin veins, has been found on the following:—

Waterside No. 1305, Zoutpansberg, Transvaal.
Halcion, Zoutpansberg, Transvaal.
Location No. 2, Bulwer, Natal.
Springfontein, Draycott, Natal.
Kelvin Grove, Loskop, Natal.
Crownlands, Himeville District, Natal.

Powdery gypsum mixed with amorphous limestone dust occurs on the farm Barroekraal, Uitenhage—nothing is known of the reserves or the grade of the material. Gypsum, probably in lumps, is supposed to exist in large quantities on the farm Wes Lemoenkop in the Kenhardt District.

GYPSUM PRODUCERS.

District.	Locality.	Owner of Rights.	Nearest Station.
Boshof............	Goede Hoop.........	C. P. van Wyk.....	Windsorton Road.
,, ...	Kleinboschvark-fontein	J. J. Kotze.........	Bosvark Siding.
,, ...	Reinhardt..........	S. Reinhardt.......	Riverton.
,, ...	Rietfontein (819)....	J. A. van Wyk.....	Windsorton Road.
,, ...	Rietpan...........	L. A. Joubert......	Riverton.
,, ...	Sleutels Poort......	J. G. Joubert.......	Riverton.
,, ...	Vrede.............	—	Windsorton Road (40 miles away).
,, ...	Weltevreden........	R. J. Voster........	Windsorton Road.
Hay...............	Saltpan...........	G. G. K. Schmidt P.O. Papkuil	Silver Streams.
Kimberley.........	Gannavlakte.......	Pretoria Portland Cement Co.	Windsorton Road.
,, ...	Jackals Pan........	J. G. Polley........	Windsorton Road.
,, ...	Rowan............	J. Havenga........	Riverton.
,, ...	Zoutpansfontein....	Nantwich Salt Works Ltd., Kimberley	Riverton.
Van Rhynsdorp.....	Gordons Hope......	I. Gordon..........	Liebendal Siding.
,, ,, ...	Holrivier..........	B. W. Hoffman & Co., Van Rhynsdorp	Liebendal Siding.
,, ,, ...	Onder-Aties.......	M. Myers, Piquetberg	Klaver.
,, ,, ...	Berg Plaats.......	P. J. Trytsman, Vredendal	Holrivier Siding.
Umsinga (Native Reserve)	Ngobevu..........	H. J. Horning, Pietermaritzburg	Ahrens.

* Explanation of Sheet No. 2 (Pienaars River). Government Printing and Stationery Office, Pretoria, 1907, p. 24.

CHAPTER IV.

THE ORIGIN OF THE SOUTH AFRICAN GYPSUM DEPOSITS.

The Deposit at Port Nolloth.

With no chemical analyses at his disposal it is impossible for the writer, after only a brief visit, to discuss the origin of our gypsum deposits except in their broadest outlines. The explanations offered are accordingly of a speculative nature—these have been set down to indicate along what lines research is necessary; possibly many phases are incapable of actual proof and here controversies will always arise.

The formation of gypsum with other non-metallic minerals from sea-water is well known and its voluminous literature need not be discussed here. Undoubtedly the saltpans near Port Nolloth and the coastal ones of the Van Rhynsdorp district owe their gypsum to the evaporation of sea-water. But massively banked gypsum beds as associated elsewhere in the world with this type of deposit do not exist in this country; the scale of operations was limited here.

The Port Nolloth pan is an inlet of the sea which has been cut off by sand dunes. Its disposition has been controlled by the strike of the westward- and seaward-dipping quartzites and the thin quartz veins which crop out on the sides of the pan. The shallow nature of the pan has been mentioned. The tendency of the gypsum is to crystallise in the underlying clay—the salt tends to crystallise on the surface of the pan; this fact is a function of their widely divergent solubilities, with the adsorptive properties of the clay accentuating this selection. The large crystals postulate stable conditions over a long period—these can exist below the surface of the pan, where diurnal and seasonal variations are strongly modified. The large crystals are limited to one portion of the pan; this may be due to a thin gritty layer occurring in the clay here, where the solutions could readily collect. The sea-water trapped by the dune barrier was and is augmented by the wind-blown spray. The characteristic heavy mists which are the airman's hazard along this coast, and the rare rains provide the water necessary for the selective action mentioned above. The moisture soaking through the surface carries the saline matter with it—thus gypsum-charged brine collects in the less pervious layers of the clay; capillary attraction during the drying process of the pan causes the bulk of the common salt to be deposited on the surface, whereas the less soluble gypsum crystallises out in the clay on the solution becoming concentrated, a negligible amount of gypsum being deposited along with the salt. Where crystallisation is very slow, large crystals can develop; successive partial solution followed by redeposition, which takes place, helps such crystals to form. The solutions in the clays are evidently never concentrated enough to allow the salt to crystallise out except in the overburden or on the pan's surface. The saliferous overburden is a mixture of wind-blown sand, with salt and gypsum derived partly from the clays below by capillary attraction and partly from the spray. The "up-and-down" movement of the solutions must be responsible for those peculiar pockets

of small gypsum crystals a few inches below the pan's surface; small crystals resulted due to the proximity of the surface where rapidly changing conditions mitigate against the production of large crystals.

Another explanation of this gypsum occurrence may be that the ocean, only about a half-mile away, is continually supplying sea-water to the pan through the well-jointed quartzites, which over such a short distance would not impede the flow very much. If such an inflow, not visible at the surface, exists, some barrier prevents the bulk of the water from spreading very far, as most of the gypsum is at the point nearest to the sea. The clay in the pan may impede and direct the progress to such an extent that conditions approximating to equilibrium exist between the inflow and that lost by evaporation.

Yet a third explanation may be offered: the quartzites in the pan have thin layers of schistose rocks intercalated—both rock types are capable of carrying sulphides; these could furnish sulphuric acid which on interaction with the clay or sea-water would ultimately yield gypsum. Possibly two or all three explanations offered play their part and more detailed work may show the true origin of the gypsum.

The Deposit on the Farm Saltpan.

The source of the salt and gypsum in the pan of the farm Saltpan, district of Hay, can as yet not be definitely solved. Several explanations of a purely speculative nature are offered:—

(1) The pan situated on the limestone of the Campbell Rand Series may represent a sink-hole which is a common feature in limestone country; or, alternatively, it may be the site of a kimberlite pipe. The salt and gypsum may have a marine origin and have been transported as dry dust by the wind, analogous to the source of the salt in the Sambhar Salt Lake in Rajputana (*vide* bibliography). The "potclay" or impure amorphous limestone represents the weathered limestone in situ and the gypsum crystallised in narrow irregular layers which corresponded to the junctions of the massively banked limestones. Here the water could more easily collect; stable conditions for crystallisation existed and large crystals developed. The layers may have formed successively—the uppermost one, where, due to the proximity of the surface, conditions were not stable, having smaller crystals than the other layers. Yet a number of springs entering the sides of the pan for some time after the rains are fresh to the taste; also the "potclay" is remarkably impervious, but the brine and gypsum are a number of feet below the surface of the pan.

(2) A better explanation, in the opinion of the writer, is to assume the presence of sulphides here. The presence of sulphides in shallow water deposits is well known and the Black Sea muds are often quoted in support. R. B. Young, in one of his papers on the Dolomite Series, says: "There is abundant evidence that several of the great

limestone formations of Palaeozoic and earlier age, including the Dolomite Series of South Africa, originated largely as calcareous muds and sands deposited in widespread shallow seas" (G.S.S.A. Vol. XXXVII, p. 153). He has developed the idea of shallow "phases" in his paper "Conditions of Deposition of the Dolomite Series" (G.S.S.A. Vol. XXXVI); on page 134 we read ". . . . suggest strongly that the series . . . was laid down on the bed of a comparatively shallow inland sea." The presence of sulphides has also been noted by him in the paper just quoted; in speaking of the boreholes cores from Doornkloof and Venterspost, he says: "Carbonaceous shaly material is of very common occurrence in the cores . . . sometimes contains metallic sulphides." Also in another paper (G.S.S. A. Vol. XXXVII, p. 168) one reads: "pyrite is sometimes present." Analyses quoted by Horwood (G.S.S.A. Vol. XIII) from the Far East Rand show for the Dolomite: ·62 per cent. and for the shale in the Dolomite: ·812 per cent. FeS_2. At Brits Halt, about 2½ miles from the pan, the writer noted a shallow well which smelt strongly of sulphuretted hydrogen. The assumption of sulphides in the country rock of this vicinity seems to have some foundation. The interaction of the limestone with the sulphuric acid produced by the oxidation of the sulphides through meteoric waters could result in the formation of gypsum. The reaction went on slowly and the stagnant drainage system of the pan did not allow the sulphuric acid to wander at will but guided it along the badly developed bedding planes; this resulted in large crystals of gypsum occurring in horizontal layers. The pan had its origin as stated above—wind-action playing its part in preserving the depression, especially as the pan is devoid of vegetation.

(3) A third theory may be found in the assumption of a former outlier of Upper Dwyka which furnished the gypsum and possibly the salt too (*vide* second para., page 31); the weathered shales were ultimately removed by the wind. Du Toit (Geol. Comm. Cape of Good Hope, 1907, p. 178) says: "The Dwyka . . . no doubt at one time overlay the whole of the Hay Division." This explanation, or one based on the assumption of a sulphate-rich saline spring, has little to commend it, yet each is difficult to refute.

The Deposits of the Kimberley and Boshof Districts.

The origin of the bulk of our gypsum deposits is somewhat better understood in its essentials. The fundamental chemical reaction underlying the formation of gypsum may be written:—

$$H_2SO_4 + H_2O + CaCO_3 \longrightarrow CaSO_4.2H_2O + CO_2.$$

The black shales of the Upper Dwyka, and in a lesser degree the dolerites, are known to carry pyrite. On weathering the pyrite yields sulphuric acid, which, if given the opportunity, will react with limestone according to the above equation—more likely, however, it will

mingle with solutions of calcium bicarbonate, and on concentration of the solution gypsum will crystallise out. This reaction may be indicated thus:—

$$Ca(HCO_3)_2 + H_2SO_4 \longrightarrow CaSO_4.2H_2O + 2CO_2.$$

Another interpretation of the process involved is to consider that the iron sulphate formed from the pyrite reacts with the calcium carbonate or bicarbonate giving calcium sulphate in solution which crystallises out as gypsum. (See footnote on page 30.)

The geological structure at the gypsum deposits is simple: the amygdaloidal lavas belonging to the Ventersdorp System undulate beneath the flat surface of the country and occasionally just reach the surface. The undulations or hummocks are in a measure the result of the intense glaciation which preceded the deposition of the horizontally lying Upper Dwyka shales; the tillite, the morainic material, appears to be missing in places so that the shales rest directly on the lavas. Deposition continued for a long time forming the younger members of the Karroo System. Igneous activity caused a huge dolerite sill to be injected into the Upper Dwyka shales or at their junction with the overlying Ecca Series. To-day erosion has removed everything above the dolerite sill and the major portion of the sill itself. The rocks outcropping are the lavas, the shales and the dolerite, which on weathering can furnish surface limestone. The base on which the acid can act is given in the weathered zone of such rocks. The reaction takes place when the chemical constituents are in solution; there is no evidence to support a metasomatic process whereby the limestone was gradually converted into gypsum, although this has been recorded from other deposits. In the absence of exact chemical data it is impossible to say to what extent each type of rock contributes—all three could conceivably have yielded one or two of the essential constituents.

At no great distance to the west of the deposits, the Vaal and Harts Rivers, flowing roughly N.N.E.–S.S.W., are following the direction taken by the former Dwyka glaciers. This direction coincides roughly with that of the Gypsum deposits on the Cape-O.F.S. border; it is no far cry to connect the formation of gypsum with the glacial valleys—the writer would prefer to refer to these as hollows, as the ice-masses met with topographical obstacles in this vicinity. In such hollows the tillite, of only a few feet thickness here and the shales of the Dwyka were deposited—later deposition covered the filled depressions as well as the lavas. Once erosion had punctured the younger dolerite sheet which has a thickness of 360 feet at Kimberley, the weathering of the shales, to which the other rocks added material in solution, could produce gypsum under certain conditions. Obviously the stagnant drainage found in the glacial hollows, once the underground water reached them, facilitated the chemical reactions; in such a locality, due to the greater rate of disintegration, a pan could result. As the formation of gypsum is a result of weathering, the climate provides another necessary condition. The formation of surface limestone is dependent upon climate—the limestone, or a phase in its formation, is a prerequisite for the formation of gypsum. A climate identical or similar to the one existing

to-day must have reigned during the weathering of the shales. A more humid climate would have caused the leaching out of the chemical constituents, nor could the concentration necessary for crystallisation have been reached. Also if the formation had been immediately preceded by a humid climate, banked gypsum would have been formed, similar to that of marine origin, and not nodular gypsum disseminated through clay. A climate with a low rainfall followed by a long dry period appears to give the most favourable conditions. During the dry period the water would be raised by capillary attraction which would lead to the concentration of the solutions within the clay causing the gypsum to crystallise out. More soluble substances would not be thrown out of solution so readily and could form an efflorescence at the surface from where the wind could easily transport it; this process has not been sufficiently stressed in the discussions on the origin of pans, as the removal of material in a different chemical combination to what it existed before it weathered must have been responsible for an appreciable lowering of the floor of the pan. The repeated crystallisation on the floor of the pan would hasten disintegration providing the wind with more suitable material for transportation. Yet the lowering of the pan's surface by such means would be partially counteracted by the swelling of the shales on weathering.

The deposits occur in ill-defined pans; those on the Griqualand-Orange Free State border appear irregularly inter-connected. This is due to the undulating nature of the glaciated surfaces beneath. The pans prevent the gypsum from being leached out.

No surface limestones exist above the gypsum deposits—here and there nodular limestone which has escaped being attacked by the sulphuric acid occurs in the clay, rarely in thin seams. This indicates that there is enough acid produced to neutralise all the calcium carbonate formed from the clay as well as that washed into the pans from its fringes which are usually composed of dolerite. Other sulphates, those of Mg and Na, can form; on the farm Reinhardt these salts—Epsom salts and Glauber salts—have been collected. These salts are very soluble and are doubtlessly carried to the surface by the upward movement of the water and then easily blown away by the wind. As common salt is also present we find that a number of complex reactions are possible in the chemical system $H_2O—Mg—Ca—Na—CO_3—HCO_3—Cl—SO_4$ with various climatological factors altering the conditions for chemical equilibrium. Much of the iron liberated has wandered upwards; the weathered shale becomes lighter coloured, perhaps iron sulphates influence the colour here, with the upper portion stained pink by the presence of the iron oxide *; much of the iron has found its way into the overburden and some has probably suffered a similar fate to the other efflorescing salts. Occasionally thin iron-rich seams are encountered in the weathered shale—these seams, with their texture differing from that of the shales, have provided suitable zones of deposition.

No visible gypsum occurs in the overburden, which is somewhat sandy. This seems to indicate that the formation is not still going on, a conclusion which in the writer's opinion is negatived by what

* Lindgren, p. 264, indicates: $Fe(SO_4) + CaCO_3 \rightarrow$ Gypsum and Limonite (from Siderite).

can be seen in the exposures. The explanation favoured is that the concentration of the rising aqueous solutions before reaching the more porous overburden is such that practically all the gypsum is deposited—the small and even minute crystals in the upper pink gypsum clay indicate how rapidly the gypsum is being precipitated here. Another factor enters here; it is a well known fact that clays adsorb the bases of salts, and some more so than others. As all South African gypsum deposits are associated with clays, it is evident that these provide a suitable sphere for the formation of gypsum. The clay aids the selective process mentioned before; it appears from the evidence in the field that nearly all the gypsum is retained by the clay, not necessarily adsorbed, whereas Glauber and Epsom salts readily reach the surface where they can be removed by the wind; but it is known that these two salts in passing through clay liberate sulphuric acid because of the adsorption of part of their bases*—this factor is not without effect on the conditions of equilibrium of the interacting chemical constituents.

It appears from what has been said that the following conditions are essential for the formation of gypsum:—

(1) Rocks capable of supplying the necessary components in the zone of weathering.

(2) Locally impeded drainage—e.g. as found in a pan.

(3) A climate with a low rainfall and a long dry period.

Perhaps a clay sphere of activity is a fourth condition—it certainly promotes the formation of gypsum.

Patches of subangular pebbles and boulders of lydianite occasionally occur in the gypsum-clay beneath the overburden at Gannavlakte; these suggest that clay was washed in from the sides of the pan and thus added its quota of material for the formation of gypsum to that furnished by the clays weathering in situ, and that taken into solution from the weathering lavas and dolerites by the circulating waters. The transported material was added during a pluvial period which interrupted the more arid conditions which set in again with the formation of the overburden whose sharply defined lower boundary indicates a sharp change in climatic conditions. On the other hand, it is quite possible that the formation of gypsum did not commence until after the overburden began to form. The flat artefact-like lydianite pebbles which lie on the surface have been washed down by the rain from the dolerite-shale contact.

The deposits of Vrede and Kleinboschvarkfontein also owe their origin to the Upper Dwyka shales, although on the small scale geological map of the Union these localities are shown well within the Ecca Series. The boundary between the two series cannot be sharply drawn here—possibly shales similar to the black shales of the Upper Dwyka do occur as a facies variation in the lower portion of the Ecca Series. One may regard, pending further investigations, Kleinboschvarkfontein as an inlier of Upper Dwyka while on Vrede a thin film of lower Ecca simulates the role of the black Upper Dwyka shales—more likely the gypsum-charged waters from the older shales found this a suitable zone for precipitation of gypsum.

* Kohler: Zeitschr. fur prakt. Geologie, 1903, p. 49.

The formation of gypsum will not necessarily be confined to the Upper Dwyka but this horizon appears to be favoured with the required constituents. Other members of the Karroo System are known to carry pyrite and the dolerites are not confined to any particular geological horizon—further deposits can be expected where the other two conditions are also satisfied. Nor is the formation of gypsum confined to the Karroo System, e.g. Dr. Haughton has informed me that the light grey clays from the Bokkeveld Series on Krom Poort East (Uitenhage District) are gypsiferous; masses of small gypsum crystalls being formed at the surface—presumably by evaporation of ascending waters.

The frequent association of common salt with the gypsum has still to be explained—e.g. in the pans near Riverton and on the farm Saltpan. A contribution of "cyclic" salt together with a certain amount of gypsum must be assumed, i.e. a marine source analogous to that proved in the case of the Sambhar Salt Lake. The pans acted like traps for the salt and gypsum. Alternatively, the salt and with it some of the gypsum have a syngenetic origin; they were imprisoned in the sediments when these were formed. The amount retained " . . . depends on the protection from leaching. The salt leaches out readily (not necessarily wholly) while considerable quantities of the gypsum may remain." (Iowa Geol. Surv. Vol. XXVIII, p. 121). It is impossible to ascertain to what extent the sources just mentioned have contributed towards the formation of our gypsum deposits.

The Deposit at Ngobevu.

In discussing the origin of this deposit du Toit says: "Hatch regarded the deposit as having been formed from the decomposition of a dolerite sheet in the Ecca Shales, but this view does not square with the facts. It is more probable that the material is the product of a mud-spring throwing out water charged with sulphate of lime from a fault line in the Dwyka. An extremely close parallel can be cited in the Isinuka Sulphur Spring near Port St. Johns in Pondoland, where a dull white material rich in gypsum is being deposited from a warm saline water that issues along a fault in the Dwyka. The Ngobevu occurrence is as a matter of fact situated not far from the Tugela fault, which dislocation is accompanied by occasional parallel fractures. On the hypothesis advanced a sheet of mud would gradually have been spread out over the terrace, dolerite boulders would have gravitated down from the hillside behind and have become embedded in it, and the sulphate of lime would during its crystallisation have tended to become concentrated near the surface of the mass."

The writer finds it difficult to subscribe to this view. The mode of occurrence here argues for a similar origin to the deposits near Kimberley and Boshof. The deposit lies in the Upper Dwyka, and these rocks, and possibly the overlying dolerite sheet, satisfy our first condition for the formation of gypsum. The faulting presumably led to the damming of the sub-surface waters whereby the second condition is satisfied. The intense erosion which is dissecting the country to-day is also leaching the gypsum deposits, i.e. the formation of gypsum has ceased; the erosion is mainly the result of

recent uplift which doubtlessly affected the climate of this region—the change in climate together with the increased erosion caused the "impeded drainage" stage to disappear. The third condition, a dry climate at the time of formation, seems to offer no undue strain on the facts. The dolerite boulders in the clay represent the residual masses of thin apophyses from the overlying dolerite which weathered with the shales while some boulders were mixed with the clay as both slipped downwards due to undercutting when the Tugela River deepened its channel.

The fact that this is the only known gypsum deposit in Natal points to some special factor—which is supplied by the faulting.

Deposits of the District of Van Rhynsdorp.

The deposits of the Van Rhynsdorp district, excepting the coastal pans, owe their origin to almost indentical circumstances with those just described. The geological series found here are the Malmesbury beds, but it is quite possible that the deposits are not entirely confined to these. Shales which have largely been metamorphosed to phyllites and schists carry pyrite, whose casts in the weathered rocks can often be seen. The Malmesbury Series consists here chiefly of limestones and is thus capable on weathering of supplying the required chemical constituents for the formation of gypsum.

The folded and faulted nature of the rocks, which are largely covered by aeolian sand and surface limestone, and the alteration of the drainage following recent uplift, do not facilitate our conception of the origin of these deposits. That a certain amount of gypsum has a marine origin must be accepted as the sea is not far distant and has only in geologically recent times withdrawn to its present position. The field-evidence suggests that even minor faults direct and dam back the waters charged with gypsum; in fact all factors influencing the underground water-flow play their part in localising and also in affecting the quality of the gypsum deposits. The location of most of the gypsum workings (*vide* p. 2) along the upper portion of the slopes is due to the water circulating in the higher-lying overburden and weathered ground seeking the drainage channels and becoming concentrated even before reaching the atmosphere whereby gypsum is deposited within the fringes of the slopes. Aeolian sands mask this process.

In addition to faults, pans or natural basins facilitated the formation of gypsum. The deposit on Berg Plaats owes its formation to a pan which has in recent times as the result of increased erosion been cut through at one end by a small stream.

Gypsum occurs here in the overburden sometimes—this is apparently only the case when the overburden is of gravel. That surface limestone can be found above gypsum deposits in this district may be ascribed to the greater mobility of the gypsum. This mobility would have caused the gypsum to be leached out but the very low rainfall allows the gypsum to wander only slowly from place to place by repeated solution and redeposition. Not only is some gypsum being leached out to-day but erosion is responsible for scattering gypsum fragments that have been laid bare. This process is mainly

responsible for the gypsum found on the surface. It seems certain that an overburden, probably because it acts as a regulator or buffer, facilitates the formation of gypsum. The climate of this area is similar to that around Kimberley—only somewhat drier. There is thus a close parallelism between the two important gypsum areas. In the Van Rhynsdorp district secondary processes are modifying the original character of the deposits and this results in a greater variation of grade and tonnage per unit area.

Small, rather angular pebbles of quartz, analogous to the lydianite ones on Gannavlakte, are sometimes found in the gypsum-clay—this might argue for transportation of some of the clay; the writer inclines to the view that these are fragments of the thin quartz veins which have been ruptured during the weathering of the phyllites and schists. These rocks on weathering experienced considerable volume changes in their alteration into clays whereby movement, evidenced by slickensided surfaces, was caused in the weathered zone. Such movement, aided by the fracturing action resulting from the repeated crystallisation of gypsum, broke up the clay and the weathering rocks and incidentally the quartz veins so that their fragments now appear scattered in the clay. The writer on rare occasions has seen thin compact seams of gypsum intercalated between almost fresh phyllites when it was possible to observe the destructive influence exercised upon the rocks by the gypsum. These seams, together with the casts of pyrite crystals, have led the writer to ascribe to the rocks rather than to the sea the position of the major contributor of gypsum.

CHAPTER V.

SOME NOTES ON THE ESTIMATION OF LUMP-GYPSUM DEPOSITS.

In estimating the tonnage of the large deposits described, a number of factors which are difficult to control must be considered. We are of course only interested in the *recoverable* amount of gypsum and not in the total gypsum present.

Due to the mode of formation the vagaries of the underground water can affect quality as well as quantity per unit area. In this respect the deposits of Kimberley and Boshof are more regular than those of the Van Rhynsdorp area where the geological features are not uniform. In this locality the extent of the deposit cannot be so accurately and readily determined because the petering out of the surface limestone at the fringes of the deposit is not characteristic here, whereas in the Boshof-Kimberley area it is. Given the areal extent of a deposit it is necessary to know what, say, a morgen can yield. Very little data exists. The writer found that the determination of an equivalent thickness of gypsum, i.e. the thickness the gypsum would have had, if it had been deposited in a regular seam, led to overestimation. This thickness is obtained by taking the mean of a number of sums of the various lengths of gypsum exposed along a perpendicular on a quarry or pit wall. More accurate results are obtainable by weighing the quantity of dried and cleaned gypsum produced from a large pit with regular and measured sides. No

figures are available from the Van Rhynsdorp area, but the tonnage per unit area will not differ materially in the deposits exploited here from those near Kimberley. With the kind co-operation of the manager at Gannavlakte, Mr. R. Long, the writer obtained data from three test pits some distance apart from each other:—

	I.	II.	III.	IV.
Overburden	2½ ft.	2½ ft.	2½ ft.	—
Gypsum-clay	4½ ft.	5½ ft.	7 ft.	—
Short Tons of Gypsum per Morgen	4,600	7,700	7,400	3,800

The fourth figure was obtained by determining the area occupied by the open-cast workings and then dividing this number into the tonnage produced from here. The figure is depressed due to several causes: efficiency in production has increased with time, thus sieving methods, although still primitive, have improved, leading to a greater recovery of gypsum; raw and new labour is necessarily wasteful; natives, when not properly supervised, have sometimes abandoned partially worked pits and even left patches unexploited—such factors have lowered the figure for the yield per morgen.

The average of the four figures lies near 6,000 short tons per morgen; in the estimates given in Chapter III, 5,000 short tons per morgen was taken as a basis. The figures cannot be accurate as this type of deposit does not lend itself to such determination, but interested parties can arrive at approximate "lives" of these deposits. The prospector or farmer once he has proved the extent of his deposit by pitting can thus readily make a rough estimate of the gypsum available.

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